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Regenerative Agriculture's Potential Carbon Storage in Nebraska Soils

Jenna McCoy

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Regenerative Agriculture’s Potential Carbon Storage in Nebraska Soils

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By Jenna McCoy

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Thesis Advisor: Dr. Katja Koehler-Cole

Thesis Reader: Dr. Rebecca Young

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Abstract

This meta-analysis investigates the possible carbon sequestration of no-till and cover crop practices on Nebraska farmlands. These management practices are part of regenerative agriculture, a farming method designed to mitigate and adapt to climate change. As climate change is expected to significantly reduce yields in Nebraska, sequestering carbon in farmlands offers a way to adapt to climate change impacts and lower the concentration of carbon dioxide in the atmosphere. However, changing management practices is difficult and is driven primarily by economics. This study aims to determine how much carbon these practices can sequester in Nebraska soil each year by evaluating the soil organic carbon (SOC) change from studies across the Midwest United States, with the goal that sequestration rates from this study can be used by Nebraska farmers to understand the returns of these management practices when coupled with carbon sequestration programs. To accomplish this, we reviewed studies investigating no-till practices (ten sites) and cover crop practices (ten sites) from the Midwest. Parameters including study length, site precipitation, and average temperature at each site were included and the relationship of those parameters to carbon sequestration rates were investigated. These parameters were not strongly correlated to carbon sequestration rates of no-till sites, though precipitation was strongly correlated to carbon sequestration under cover crops. A mean carbon sequestration rate for no-till (0.417 ± 0.54 Mg ha^{-1} yr^{-1}) and cover crops (0.136 ± 0.11 Mg ha^{-1} yr^{-1}) were calculated. Using the mean carbon sequestration rates for each management practice, Nebraska soils could store a total of 4,980,339 Mg C each year by using both no-till and cover crops on all farmlands, offsetting half of Nebraska's agricultural emissions.

Introduction

Climate change is expected to lower yields in some parts of Nebraska by as much as 50% and accelerate soil loss under the high emissions scenario in the Fourth National Climate Assessment (USGCRP, 2018). At the same time, agriculture contributed 10% of the United States overall greenhouse gas emissions, including 78% of the United States emissions of nitrous oxide (EPA, 2020), a gas with a warming power 300 times stronger than carbon dioxide. Climate change's effects on precipitation and temperature trends drives a need for improving agricultural soils to feed a growing population, spurring research for solutions for this regional and global problem. Fortunately, agriculture is one of the few sectors able to mitigate its emissions, as well as adapt to climate change by sequestering carbon (USGCRP, 2018; Sykes et al., 2019). One of these mitigation and adaptation strategies is known as regenerative agriculture.

There are many synonyms for regenerative agriculture, such as sustainable agriculture, holistic agriculture, climate-smart agriculture, and carbon farming. It can also be defined by its conservation practices: having cover crops, not tilling the soil, farming organically, and integrating livestock. Sometimes it is even defined as being farming that focuses on soil health. The practices used for these management descriptors have a common thread: increasing the soil's capability to function, often by adding carbon to the soil. For simplicity, the variety of practices will be called "carbon farming" due to their carbon sequestration effects. This project will focus on researching the carbon capture potential of Nebraska soils to address current financial barriers for implementation of carbon farming practices, with a primary focus on no-till and cover crops.

Tillage practices vary in managing and storing carbon, ranging from the extremes of conventional tillage and no-till, with several practices somewhere in the middle. Conventional tillage is the most common method of tilling the soil. In the past, the moldboard plow was most common, which inverted the soil surface. Today in Nebraska, disk tillage is considered the conventional tillage practice, as most farmers who till use disc tillage systems (Interview: Jasa, 2020). These systems use concave metal disks angled slightly to slice into the soil, which cut up residue and incorporate it into the soil, and are used across about 27% of Nebraska's cropped acres (Rempe, 2019).

One tillage practice that disturbs less soil than conventional tillage and more than no-till is strip tillage. Strip tillage involves tilling strips of soil only where crop seeds are to be planted (Brainard et al., 2017). This allows seed distributions to be the same as for conventional tillage while disturbing the soil less. Combined with other management practices and appropriate width of strip-tilled vs non-tilled sections, strip tillage could help store carbon deeper in the profile compared to no-till practices, resulting in a net storage of carbon in agricultural fields. Strip tillage also integrates nutrients and residues from the surface more evenly into the soil profile (Ogle et al., 2019), which may improve the effectiveness of incorporating organic matter on the surface from manure or sewage sludge applications. Although part of encouraging the use of strip till practices is to mix nutrients that would otherwise become separated in the soil, or stratified, this isn't wholly supported by research. Studies have shown that nutrients such as K (potassium) and P (phosphorous) become stratified under no-till systems (Teboh, 2016), but it doesn't have a significant impact on yields (Grove, Ward, & Weil, 2006) and overall decreases phosphorous loss (Daryanto, Wang, & Jacinthe, 2017).

On the other hand, no-till is used on 46.1% of Nebraska's acres (USDA-NASS, 2017). Under no-till practices, farmers do not till the soil. Instead, farmers use herbicides to control weeds, drill the seeds directly into the soil surface, and may use injection methods to incorporate needed fertilizer amendments. Leaving the soil surface intact reduces the loss of soil carbon, lowering the loss of organic matter by decomposition as it is less exposed to the elements (Palm et al., 2013). This also benefits the soil by allowing soil structure to develop, which can improve the rate of water infiltration and water storage in soils (Palm et al., 2013). Past studies examining no-till by itself may have overstated the benefits of no-till, as more current sources are showing the amount of carbon stored may be less than previously expected (Luo, Wang, & Sun, 2010). Additionally, some research indicates that tilling stores carbon deeper into the soil profile, as opposed to carbon storage in the upper soil layers due to no-till (Ogle et al., 2019). The carbon stored deep into the soil profile remains there for longer, as it beyond the reach of decomposers.

Another management method that has been shown to improve biological diversity and carbon sequestration in the soil is the use of cover crops. Across Nebraska, only 3.3% of Nebraska's acres are cover-cropped (USDA-NASS, 2017). Cover crops are grown during the fallow season and are not harvested (Chatterjee et al., 2020). They provide cover for the soil surface from precipitation as well as food for soil microbial life while increasing the carbon present in the soil from plant roots (Huang et al., 2020). These roots also stabilize the soil against erosion (Interview: Basche, 2020). Cover crops are especially valuable as a carbon-capturing solution for climate change when used in concert with other practices.

Cover crops combined with no-till agriculture management is a popular area of research in the realm of carbon farming. The combination of these practices stores more carbon in the soil and minimizes disturbance (Brainard et al., 2017; Hill et al., 2020; Huang et al., 2020), increasing the benefits of each system (Interview: Hatfield, 2020). One of these practices alone is not likely to provide the solutions farmers and the climate system need (Interviews: Basche and Hatfield, 2020).

However, there are substantial barriers to implementation. These practices need to benefit farmers financially, as producers are more likely to adopt new methods for economic reasons (Kasu et al., 2019; Interview: Berns, 2020). Currently, financial support to implement these practices is limited, making farmers less likely to transition their fields (Kasu et al., 2019). These practices may also add risk and complexity to existing farm systems, especially since cover crop planting and termination dates must be meticulously planned for maximum effectiveness (Ruis et al., 2020).

There are some possible solutions, one of which comes from carbon credits. Companies such as Indigo Ag and Nori record the amount of carbon in the soil at the beginning and end of the season, paying farmers for increasing the amount of carbon in their soil. One carbon credit is equal to storing one metric ton of carbon in the soil (Merriam-Webster, n.d.). The carbon credits are then purchased by other companies to offset their own emissions in what is called a carbon market (Alexander, 2015). This could provide incentive to change management practices and be an additional income source. Another way to make this financially viable is to place value on the ecosystem services gained from these practices (Meehan et al., 2013). These ecosystem services are things such as clean water and air. The nonprofit Ecosystem Services Market Consortium pays producers for sequestering carbon and providing ecosystem services. Government agencies such as the USDA-NRCS have existing programs for implementing conservation practices (Interview: Hird, 2020). Programs from the USDA-NRCS include converting more conventional practices to no-till management and adding cover crops. Two of these programs are the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP) (Natural Resources Conservation Service, n.d. -b).

Many people around the United States recognized the hardships that Nebraska farmers and ranchers went through in the devastating spring flood events in March of 2019. Even if fields were not flooded by a river, the high amount of rain had significant erosion impacts on farmers' fields. Culturally and economically farming is very important to Nebraska. Ninety-five percent of farms in the state are family farms (USDA-NASS, 2017), and many citizens have a direct relationship to a farmer. Research such as this may help producers and land managers make their fields more resilient and profitable while benefitting the environment, the broader community, and economy. As farmers are vital to rural Nebraska's communities, finding better ways to help farmers mitigate climate change and keep them in business is of state-wide importance.

The goal of this project is to investigate the potential carbon sequestration rates from using these management practices in Nebraska, which could be useful information for future research on the potential economic benefits of establishing carbon credit markets. Determining a singular carbon sequestration potential for the entire state is complicated by the multitude of soil properties and ranges, but investigating soil textural types that are abundant in the Nebraska landscape may provide a rough estimate of actual carbon sequestration.

Methods

This meta-analysis began with a systematic literature review to gain insight on carbon capture potentials based on the management practice studied: cover cropping or no-till management. The design and approach were modeled on the meta-analysis done by Bai et al. in 2019, where data from peer reviewed studies was extracted for analysis. Articles were identified using Google Scholar. The search keywords were “soil carbon” and “no-till” for tillage studies and “soil carbon” and “cover crop” for cover crop studies. Only peer-reviewed studies published between 1995 and February 2021 were included. All selected studies met the following inclusion criteria: (a) soil organic matter (SOM) or soil organic carbon (SOC) was measured in field experiments; (b) experiment location was within the Midwest region of the United States (North Dakota, South Dakota, Minnesota, Wisconsin, Illinois, Iowa, Kansas, and Nebraska); and (c) information including experiment duration and sampling depth was provided. The region was limited to the Midwest to reduce effects of climate differences on sequestration (Bai et al., 2019; Griffin & Edwards, 2020). Both statistically significant and not statistically significant results were included to reduce bias. Twenty study sites were selected, of which ten investigated no-till practices and ten investigated cover crop practices. Six investigated cover crop effects when in no-till management. Most studies had several sites, and where this was the case, sites were investigated separately due to different soil types and climate. In total, there were ten sites for each management practice.

Data recorded from the literature review includes the resulting values of carbon sequestration rate, the soil textural type, the management practice or practices studied, length of study, sampling depth, if the study was statistically significant and the level of significance, and climate data. Carbon sequestration rates were determined as the change in soil carbon over time for no-till studies and the change in soil carbon versus the control group for cover crop studies. For both no-till and cover crop studies, the average of the respective treatment was used. For cover crop studies, this was the average of all cover crop combinations as the purpose of this study was not to compare the effectiveness of specific cover crop species. The soil textural type of each site was recorded, using the categories of the USDA soil textural triangle (Natural Resources Conservation Service, n.d. -b). Statistical significance of the site was based on the noted significance and level of treatments. In cover crop studies, the study was considered significant if all cover crop treatments were statistically significant in the source study. Climate information was recorded as the climatological normal (30-year mean) of the site’s average annual temperature (°C) and precipitation (mm). The climatological normal does not represent the observed conditions of each site, and climate data of the nearest town was used if not provided in the study. For sites where climate normal were not included, climate data was retrieved from the National Centers for Environmental Education’s 1981-2010 Climate Normals tool (National Centers for Environmental Information (NCEI), n.d.).

To compare the results of studies conducted over a different period of time, all results were converted to megagrams per hectare per year. This accounts for differences in soil density and sampling, which varied across studies. As a megagram is equal to a metric ton (one thousand kilograms), carbon in these units represents carbon credits per hectare (Merriam-Webster, n.d.). This was computed as following:

$$\mathrm{SOC} = \frac{\left[\mathrm{SOC\%} * \mathrm{Bulk\ Density}\left(\frac{kg}{m^3}\right) * \mathrm{Sampling\ Depth(m)} * \frac{10{,}000\ m^2}{1\ ha} * \frac{1\ Mg}{1{,}000\ kg}\right]}{Time\ (yr)}$$

For studies where results recorded soil organic matter instead of organic carbon, results were multiplied by 0.58, as 58% of organic matter is carbon (Griffin & Edwards, 2020). Data was grouped by management practice and analyzed quantitatively, and mean carbon sequestration from each practice was calculated with Microsoft Excel's "AVERAGE" function. The Pearson correlation of site sequestration rate with temperature, precipitation, study length, and initial SOC content or control group SOC (for no-till and cover crop sites, respectively) were calculated separately using Microsoft Excel's "CORREL" function. The standard deviation and the 95% confidence interval were also calculated for each practice, using the "STDEV.S" and "CONFIDENCE.T" functions in Microsoft Excel.

To calculate the current and potential carbon sequestration of these practices over the state of Nebraska, the average sequestration rate of each practice was multiplied by the area of farmland in Nebraska where that practice is used and not used, respectively. The potential yearly carbon sequestration of Nebraska was calculated as if all farmland in Nebraska was under both management practices. Nebraska's total farmland area, total farmland under no-till, and total farmland under cover crops was retrieved from the 2017 Census of Agriculture for Nebraska. This data was in acres and converted to hectares, where one hectare equals 2.471 acres.

Table 1: Summary information of study sites. Temperature (°C) and precipitation (mm) are the 30-year normal of average yearly temperature and precipitation, respectively. The control soil organic carbon (SOC) content for the cover crop practice was the soil organic carbon content of non-cover cropped areas, and the control SOC of the no-till practice was the SOC content of no-till sites prior to implementation. C represents the yearly carbon sequestration of each site (Mg ha^{-1} yr^{-1}).

Practice	Soil Type	Location	Length (yr)	Temp. (C)	Precip. (mm)	SOC (Mg ha^{-1})	C (Mg ha^{-1} yr^{-1})	Authors
cover crop	silt loam	Kansas	5	12.1	489	9.90	0.29	(Blanco-Canqui et al., 2013)
cover crop	silt loam	Illinois	12	14.7	1252	26.30	0.45	(Olson et al., 2014)
cover crop	silty clay	Nebraska	4	8.7	736	16.14	0.03	(Ruis et al., 2020).
cover crop	silty clay loam	Nebraska	4	9.9	747	13.15	0.04	(Ruis et al., 2020).
cover crop	silt loam	Nebraska	4	10.2	711	13.85	-0.09	(Ruis et al., 2020).
cover crop	loam	Iowa	3	9.1	881	20.32	0.11	(Kaspar et al., 2006)
cover crop	silty clay loam	Nebraska	16	9.9	747	14.10	0.08	(Liebig et al, 2002)
cover crop	loam	Iowa	10	8.7	974	18.01	0.15	(Moore et al., 2014)
cover crop	silt loam	South Dakota	3	6.2	617	16.06	0.05	(Chalise et al., 2019)
cover crop	silt loam	Wisconsin	4	7.9	924	15.49	0.26	(Jokela et al., 2009)
no-till	silt loam	North Dakota	12	5.9	456	39.40	0.233	(Halvorsen et al., 2002)
no-till	silt loam	Illinois	12	14.7	1252	26.80	-0.042	(Olson et al., 2014)
no-till	silt loam	Kansas	10	12.8	905	9.00	0.74	(Mikha & Rice, 2004)
no-till	clay loam	Iowa	7	7.9	848	44.60	1.39	(Al-Kaisi et al., 2005)
no-till	silty clay loam	Iowa	7	7.9	775	35.70	0.69	(Al-Kaisi et al., 2005)
no-till	loam	Iowa	7	7.8	940	38.00	0.61	(Al-Kaisi et al., 2005)
no-till	silty clay loam	Iowa	7	7.1	792	30.30	0.37	(Al-Kaisi et al., 2005)
no-till	silty clay loam	Iowa	7	10.0	997	38.90	1.24	(Al-Kaisi et al., 2005)
no-till	clay loam	Iowa	3	9.7	910	43.50	-1.30	(Al-Kaisi et al., 2005)
no-till	silt loam	Illinois	44	14.1	1058	18.70	0.23	(Walia et al., 2014)

Results

Table 2: Statistical information of each practice and correlation coefficients between selected parameters and carbon sequestration rates of each practice. C represents the yearly carbon sequestration rate of each practice (Mg ha^{-1} yr^{-1}). Temperature correlation was done using the 30-year normal of average temperature (°C). Precipitation correlation was done using the 30-year normal of yearly precipitation (mm). Control soil organic carbon (SOC) for no-till was the SOC content of the soil prior to applying the no-till treatment.

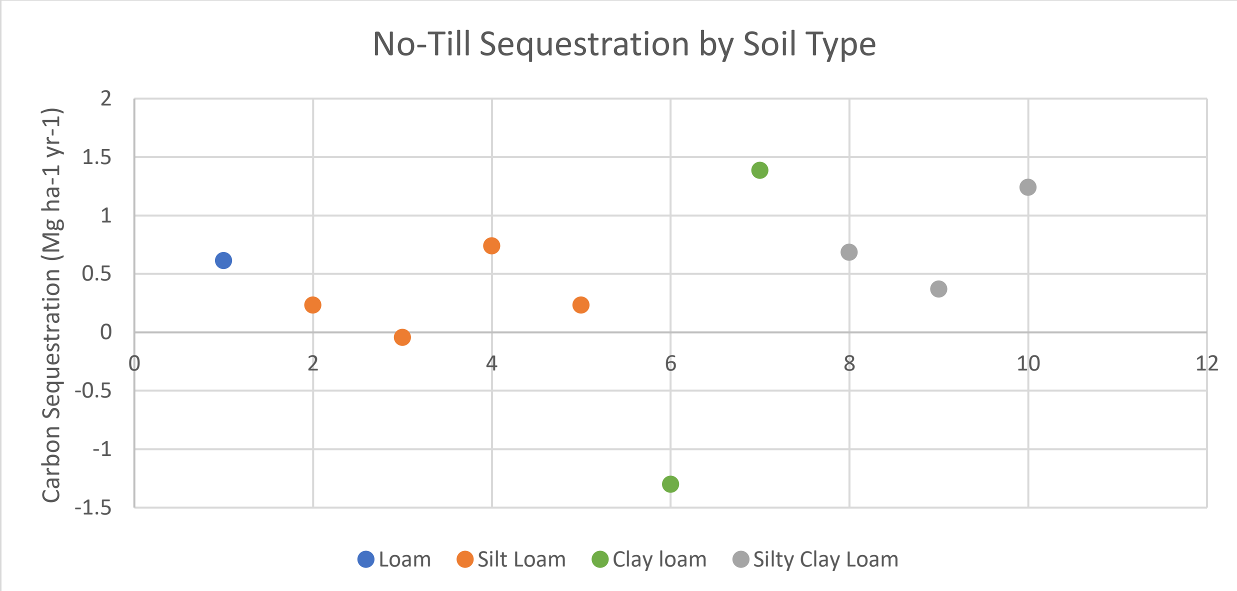
Practices	C Statistics			Correlations			
	C (Mg ha^{-1}yr^{-1})	Standard Deviation	95% Confidence Interval (Mg ha^{-1} yr^{-1})	Temp.	Precip.	Control SOC	Study Length
No-till	0.417	0.75	-0.12 to 0.95	-0.17	-0.08	-0.04	-0.02
Cover Crop	0.136	0.16	0.03 to 0.25	0.61*	0.54	0.47	0.34

**Strong correlation*

Carbon sequestration under no-till was three times higher than for cover crops (Table 2). However, no-till had greater variability of C sequestration, shown in the higher standard deviation. Additionally, the variability under no-till was significant enough to indicate the true carbon sequestration rate of no-till is zero or that no-till may cause a consistent loss of soil carbon. Cover crops, although having a lower yearly carbon sequestration rate, are highly unlikely to cause a loss of soil carbon over time.

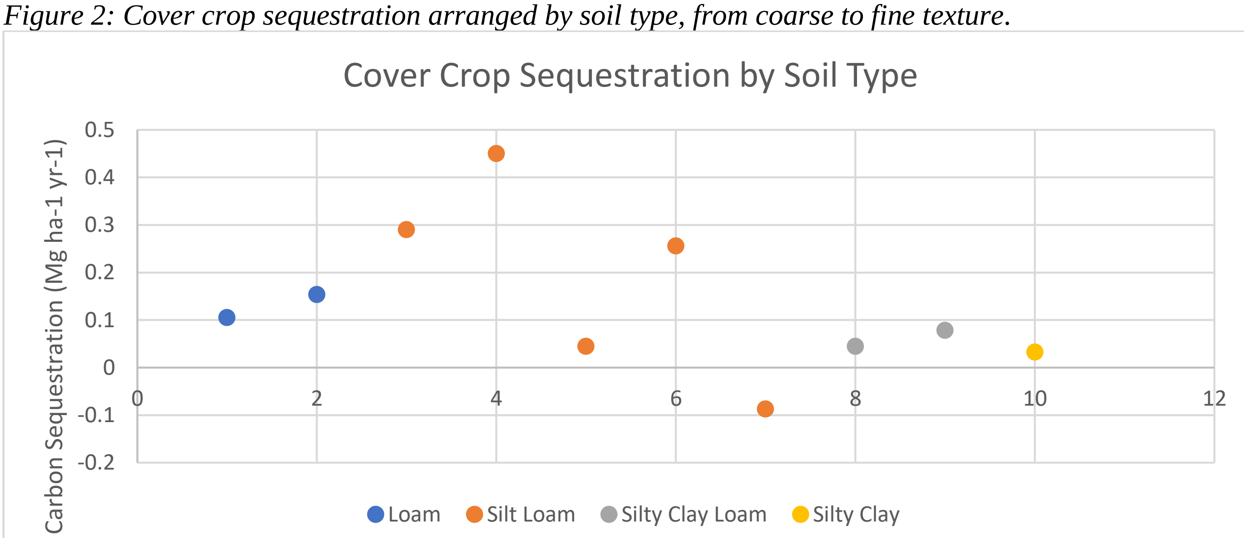
No-till was not strongly correlated with climate parameters, initial SOC, or study length (Table 2). Cover crops were more strongly correlated with these parameters, having a strong correlation (0.61) with average temperature and a moderate correlation with both precipitation (0.54) and control SOC (0.47). The moderate correlation to control SOC may be due to warmer and wetter conditions being more favorable to growth of both cover crops and cash crops, increasing the SOC gain under both.

Figure 1: No-till sequestration arranged by soil type, from coarse to fine texture,



There was no clear connection between soil texture and carbon sequestration rate under no-till. Although there is a general increase in sequestration from the coarse-textured soils (left) to the fine-textured soils (right), clay loam sites had the highest and lowest sequestration rates.

Figure 2: Cover crop sequestration arranged by soil type, from coarse to fine texture.



The connection between soil texture and carbon sequestration was also not apparent for cover crop practices, (Figure 2). Similar to the no-till sites, the soil texture with the lowest carbon sequestration, a net loss of carbon, occurs in the same soil texture with the peak carbon sequestration rate.

Table 3: Potential yearly carbon storage from selected management practices in the state of Nebraska. Current, potential, and total carbon sequestration are based on the area currently under, not under, and total farmland in Nebraska, respectively, times each practice's mean carbon sequestration rate.

Management Practice	**Area under practice (ha)**	**Current C sequestration (Mg yr^{-1})**	**Area not under practice (ha)**	**Potential C sequestration of for area not currently under practice (Mg yr^{-1})**	**Total C sequestration if all NE farmland was under practice (Mg yr^{-1})**
No-Till	4,150,862	1,728,959	4,850,406	2,020,340	3,749,299
Cover Crop	302,666	41,394	8,698,603	1,189,652	1,231,046

Table 3 shows the current carbon sequestration in Nebraska is about 1.73 million metric tons of carbon per year. Considering the amount of farmland not under these regenerative agriculture practices, an additional 3.21 million metric tons of carbon could be stored in the state's soils each year. If both no-till and cover crops were used on all Nebraska farmland, 4.98 million metric tons of carbon could be stored each year.

Discussion

Although no-till sequestered more SOC on average and has the potential to store more than cover crops if adopted across Nebraska, the 95% confidence interval of -0.12 to 0.95 (Mg ha^{-1} yr^{-1}) indicates it is possible that no-till does not cause a gain in SOC (Table 2). Other no-till studies have recognized the possibility that no-till does not significantly affect SOC (Halvorson et al., 2002; Kessavalou et al., 1998; Luo, Wang, & Sun, 2010). This increase may be due to no-till causing cooler and wetter soil conditions, lowering the mineralization rate and conserving more SOC than other tillage systems (Al-Kaisi, Yin, & Licht, 2016; Palm et al., 2013). In other words, no-till systems lose less SOC than other tillage methods. However, the meta-analysis by Palm et al. (2013) found no-till had higher or equal SOC concentrations in 93 of 100 comparisons within the 0-30 cm depth range when compared to conventional tillage after five years or more of implementation. Additionally, variability in the SOC sequestration rate across no-till sites can be attributed to differences in soil physical, chemical, and biological properties not included in this study (Al-Kaisi, Yin, & Licht, 2016; Bai et al., 2019).

Cover crop SOC sequestration variability (Table 2 & Fig. 2) may be due to properties specific to the cover crops grown. Cover crops which produce higher amounts of reside tend to increase SOC sequestration rates (Palm et al., 2013). The nitrogen content of the cover crop also affects SOC, as Villamil et al. (2006) found significant differences in carbon sequestration between cover crop rotations with and without hairy vetch, a cover crop whose residue has a high carbon content. Rotations without hairy vetch had a lower carbon sequestration rate. Cover crop mixes with multiple species also vary in their effectiveness compared to single-specie cover crop treatments (Ruis et al., 2020). Interactions between the crop phase and cover crop can also have an effect, as cereal rye grown in the soybean phase increased SOC more than the corn phase in a corn-soybean system (Kaspar, 2016).

Climate also has a significant impact on carbon sequestration under no-till and cover crops according to prior meta-analyses, though a strong correlation to temperature was only identified for cover crops (Table 2) in this study. In a meta-analysis of over 400 studies, Bai et al. found that soil organic carbon content of soils across the US are positively related to precipitation (more plant growth) and inversely related to temperature (less decomposition), although precipitation has a stronger effect (Bai et al., 2019). In other words, a cold and wet climate builds SOC faster than a hot and dry climate making it have a higher carbon sequestration rate. The authors also found cover crops and no-till increased sequestered carbon in wet and dry climates, though both sequestered more carbon in arid soils (2019). However, a study conducted in Nebraska did not find significant differences in soil carbon from a 4-year cover crop treatment, although cover crop biomass production was low (Ruis et al, 2020). Another study conducted in Kansas noted rainfall input may dictate cover crop biomass, and thus SOC differences over time (Blanco-Canqui et al., 2013).

Other factors affecting carbon sequestration rates in soil are soil texture and the length of the study. Although this study did not identify strong connections between regenerative agriculture practices with texture (Fig. 2 & 3) or study length (Table 2), this has been found in other studies. Fine-textured soils have a higher amount of SOC storage capacity, and generally retain SOC for longer periods of time than coarse-textured soils (Bai et al., 2019). The meta-analysis by Bai et al. also noted cover crops had a more significant effect while no-till had a lower effect in sandy soils (2019). The length of the study also has an effect, as no-till and cover crops generally have a greater effect over a longer period of time (Bai et al., 2019). For timespans less than ten years, SOC storage is highly variable (Al-Kaisi, Yin, and Licht, 2016), so variability in SOC storage may account for much of the variability noted at no-till (Table 2 & Fig. 1) and cover crop sites (Table 2 & Fig. 2).

Together, use of no-till and cover crop regenerative management practices in Nebraska can offset a significant portion of the state's agricultural emissions. Current carbon sequestration due to current use of these practices (Table 3) is equal to approximately one-sixth of agriculture's yearly emissions in Nebraska (Holley & Liska, 2018; EPA 2018). The potential carbon sequestration of 4.98 million metric tons of carbon per year with both no-till and cover crops on all Nebraska farmland (Table 3) is just over half of Nebraska's agricultural emissions, and about one-fifth of Nebraska's net emissions in 2016 (Holley & Liska, 2018; EPA 2018).

There are some limitations to the yearly potential carbon sequestration of no-till and cover crops in Nebraska. Foremost, few sites were of the coarse-textured soils common in western Nebraska. As the proportion of soil textures studied are not representative of the soil textures across the state, the sequestration rate does not address variability due to texture statewide. Secondly, since sampling was limited to the topsoil for all sites, changes in carbon storage deeper in the soil profile may not be represented and deeper sampling may show no net SOC benefit (Walia et al., 2017). Though six of the ten selected cover crop sites were under no-till, the effect of combining no-till and cover crops compared to just using cover crops was not analyzed. Complex interactions within the soil where cover crop residues are more protected from decomposition due to no-till may increase SOC more than using cover crops alone (Palm, Blanco-Canqui, DeClerck, Gatere, & Grace, 2013). Additionally, the potential for storing soil carbon may decrease when water is limited (Palm, Blanco-Canqui, DeClerck, Gatere, & Grace, 2013), possibly making the storage of 3,749,295 Mg per year for no-till and 1,231,044 Mg per year for cover crops an overestimate for soils in the more arid Nebraska panhandle.

Conclusion

This project set out to study the effect of no-till and cover crops management practices on soil organic carbon sequestration in Nebraska's climate and soils. We analyzed the yearly carbon sequestration rates of ten no-till and ten cover crop sites and found that carbon sequestration was more variable for no-till than for cover crops. No-till had a mean carbon sequestration rate of 0.417 Mg ha^{-1} yr^{-1} while cover crops had a mean carbon sequestration rate of 0.136 Mg ha^{-1} yr^{-1}. The amount of carbon that could be sequestered in Nebraska soils if both no-till and cover crops were used on all Nebraska farmland totaled just under 5 million megagrams per year, approximately one-fifth of Nebraska's net emissions in 2016 (Holley & Liska, 2018; EPA, 2018). As the majority of soil organic carbon is found in organic matter (Mikha & Rice, 2004), farmers could see other soil benefits such as improved aggregation, water infiltration, and reduced erosion (Palm et al., 2013). Additionally, sequestration rates of these management practices can be used by farmers to gauge risk of changing these management practices on their farms when paired with a carbon sequestration program.

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Personal Communication Sources: Interviews

Basche – Interviewed Dr. Andrea Basche of the horticulture department on September 25, 2020. She has experience in researching and evaluating crop systems, including cover cropping and no-till.

Hatfield – Interviewed Dr. Jerry Hatfield on September 29, 2020. Dr. Hatfield is a former soils scientist with the Agricultural Research Service that focused on sustainable agriculture and evaluating farm systems.

Hird – Interviewed Aaron Hird, NRCS's soil health specialist on October 9, 2020. On top of working for the Natural Resources Conservation Service, he is part of Nebraska's Soil Health Taskforce, which is creating a plan for Nebraska built on soil health measures like organic matter, biological activity and diversity, and soil structure to assess soil health in the state.

Jasa – Interviewed Dr. Paul Jasa of UNL Extension on October 6, 2020. Dr. Jasa maintains fields at the UNL-owned Rogers Memorial Farm and manages agricultural research plots on the site.